World Academy of Science, Engineering and Technology
International Journal of Biotechnology and Bioengineering
Vol:16, No:05, 2022

Machine Learning and Metaheuristic Algorithms in Short Femoral Stem Custom Design to Reduce Stress Shielding

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Abstract : Hip replacement becomes necessary when a person suffers severe pain or considerable functional limitations and the best option to enhance their quality of life is through the replacement of the damaged joint. One of the main components in femoral prostheses is the stem which distributes the loads from the joint to the proximal femur. To preserve more bone stock and avoid weakening of the diaphysis, a short starting stem was selected, generated from the intramedullary morphology of the patient's femur. It ensures the implantability of the design and leads to geometric delimitation for personalized optimization with machine learning (ML) and metaheuristic algorithms. The present study attempts to design a cementless short stem to make the strain deviation before and after implantation close to zero, promoting its fixation and durability. Regression models developed to estimate the percentage change of maximum principal stresses were used as objective optimization functions by the metaheuristic algorithm. The latter evaluated different geometries of the short stem with the modification of certain parameters in oblique sections from the osteotomy plane. The optimized geometry reached a global stress shielding (SS) of 18.37% with a determination factor (R^2) of 0.667. The predicted results favour implantability integration in the short stem optimization to effectively reduce SS in the proximal femur.

Keywords : machine learning techniques, metaheuristic algorithms, short-stem design, stress shielding, hip replacement
Conference Title : ICBBE 2022 : International Conference on Bioinformatics and Biochemical Engineering
Conference Location : Barcelona, Spain
Conference Dates : May 26-27, 2022